

TOWARDS THE SUCCESSFUL INTEGRATION OF DESIGN THINKING IN INDUSTRIAL DESIGN EDUCATION

Omar Mubin¹, Mauricio Novoa¹ and Abdullah Al Mahmud²

¹Western Sydney University, Australia; ² Swinburne University of Technology, Australia

ABSTRACT

This paper narrates a case study on design thinking based education work in an industrial design honours program. Student projects were developed in a multi-disciplinary setting across a Computing and Engineering faculty that allowed promoting technologically and user driven innovation strategies. A renewed culture and environment for Industrial Design students emphasized seeking functionality and fidelity, user and society value over beauty and form factors alone. The pedagogical approach sought to determine the new industrial products reality with an increasing contribution by design thinking and its associated methodologies that are currently advancing typical Industrial Design. In conclusion, the authors propose a number of reflections as recommendations, which may be useful for educational institutions contemplating similar curriculum makeovers to their design degrees.

KEYWORDS

Industrial Design, HCI, Design Thinking, and Design Education

1. INTRODUCTION

Industrial Design (ID) was traditionally thought of as a paradigm of constructing, designing and mass production of physical products. However, currently the discipline from an educational viewpoint finds itself in a dilemma with the growth of advanced manufacturing, technological advancements and the need for a maker culture. In Australia this dilemma is further aggravated as industrial design is still greatly geared towards industrial era manufacturing. Importantly, manufacturing was a traditional stronghold of national economy and development in the country. However, studies show that sector has fallen progressively. Australian Bureau of Statistics (Kryger, 2014) shows a more complete decline in 40 years to lows of 6.8% GDP to the period 2012-13. The commercial challenges to the discipline have also mirrored in the various educational establishments both within and external to Australia.

The lack of clarity, vision and direction of ID Education in the current day and age has been discussed by many practitioners and researchers; Donald Norman in particular. Norman has pointed out (Norman, 2010) regarding the challenges of the current times facing Industrial Design Education. He manifests a clear requirement of Design to be treated as a multidisciplinary domain with borrowings from Science, Psychology, Computing and Engineering. According to Norman altering the mindset of educators and the students is difficult and requires changes to the pedagogical setup from the bottom up and designers and design students are having to engage in the online development of skills which are traditionally not provided in design curricula. The positioning of Design Education as a research-led endeavor has also been fraught with various obstacles, with designers unsure of how best to incorporate science and empirical research in their projects. The reasons of the uncertainty and nature of stalled revamps for Industrial Design programs has been discussed in research (Bronet et al., 2003), industry and education; including: hosted by and orphaned into larger non-technical schools (such as Architecture and Arts), disassociation with science and data, over-indulgence in aesthetics and sketching, dissemination through non-literary and non-conventional forms, etc. As a consequence, several education programs are initiating curriculum changes to better suit them to the growing demands of today's digital and advanced world.

At the Western Sydney University, within the School of Computing and Engineering, Industrial Design is one of the key undergraduate programs. The School considers the Industrial Design program to play a central role binding the other disciplines of Engineering, Computing, Construction and Mathematics. Fresh entrants to the Industrial Design program usually complete a major in Design and Technology in high school spread across their final years. To date the focus of this major is primarily on aesthetics, hand crafting of products and otherwise, drawing and art based skills. Therefore the students upon entry to the Industrial Design program are unable to rapidly address to the aspects of problem-based design, maker culture or quick and dirty prototyping. This is in complete contrast to children in primary school who are learning programming from very young ages (Mitchell, 2015). In order to understand the assimilation of our students to the new way of thinking and approaching Industrial Design we have begun our efforts of a change in ideology with a top to bottom approach starting with the more mature final year students. We have trialed an induction of a design thinking approach and its associated aspects of user-centered design, interactive technology and maker culture in the 4th year honours/thesis projects.

Design thinking merged with Human Computer Interaction (Ciolfi and Cooke, 2006) - i.e. innovation driven by the design of interactive technology; can perhaps provide the required thrust to the rather stale traditional ID education practiced in Australia. In recent years design thinking has created tremendous awareness and its popularity has expanded across several industries and domains such as business and management (Dunne and Martin, 2006), social innovation (Dunne and Martin, 2006, Brown and Wyatt, 2015). The intertwining of HCI and design thinking has been of interest in the research community particularly through the notion of research through design (Zimmerman et al., 2007), where interaction designers are provided with tools to project and verify their research. Many researchers strongly support and encourage the free mingling of the two disciplines of HCI and ID (Overbeeke and Hummels, 2012) with many HCI researchers terming Design led characteristics (such as sustainability, ethics, entrepreneurship, social responsibility, etc.) as a key pillar of HCI research (the others being technology, cognition and ethnography) (Blevis et al., 2015). Gradually the two disciplines are converging particularly as HCI researchers contemplate societal aspects and designers seek to adopt technological developments (Overbeeke and Hummels, 2012). In addition design thinking and HCI are seamlessly beginning to co-exist through methodologies such as user-centered design and rapid prototyping in particular across HCI curricula (Culén and Følstad, 2014). However we do not find a well-documented account in literature of design thinking based approach through Industrial Design programs as we intended to follow to reinvigorate our ID curriculum. In sum, in our pedagogical approach we sought to determine the contribution of design thinking towards advancing typical Industrial Design final year projects. In this paper we present a case study based account of two fourth year undergraduate honours projects; co-supervised by two of the authors where we witnessed a marriage of HCI led innovation surge and design thinking towards industrial design research. We conclude with reflections and recommendations, which may be useful for educational institutions contemplating similar curriculum makeovers to their design degrees.

1.1 Our Pedagogical Approach

At the Western Sydney University, Blooms Taxonomy (Bloom, 1971) is dominant throughout the institution with a variety of influences according to discipline. For Industrial Design, it represents a way to connect and have a common understanding with other disciplines within the School and university. It brings about experimentation and playing with ideas as a way of continued prototyping and iteration; reminiscent of the design thinking based DIY, interaction and maker culture (Lindtner et al., 2014).

The Industrial Design undergraduate degree at the Western Sydney University is offered as a four-year course with the final year conducted as a year long honours/thesis project. It is worth mentioning that only students who attain an average grade of credit or above (> 65%) are invited to the honours program and hence are the best performing students of the course. The honours program is structured as a 70-credit point embedded degree where students complete a design research project under the supervision of an academic. The assessment criteria are based around the form and function of a tangible and physical product (model), which forms the main deliverable of the program besides a thesis document. All assessments are marked by independent examiners in a peer review format. Students enrolled in the honours program (class strength typically ranges from 10-12 in number) convene once a week (28 times in a year spread over two 14 week semesters) for a 2 hour practical lecture followed by a flexible and 4 hour workshop and supervision block. It

is not uncommon for students to meet with their supervisors outside the timetabled hours. In the case of the student projects presented and discussed in this paper the first two authors functioned as co-supervisors whereas additionally the first author was the honours coordinator and the second author the director of program in ID. Therefore it was possible to transmit the required design thinking and HCI innovation skills both in breadth (class discussions) and depth (individual supervisory meetings) across the two projects by the two member supervisory panel.

The following were the main elements of supervision; advice and training provided to the students that would provide the required level of and support the integration of design thinking and HCI skills:

1. Facilitating User-centered design and acquiring user empathy through:
 - (a) Training on conducting participatory design and brainstorming work- shops
 - (b) Formulation of research methodology via IDEO Cards (Ideo, 2003)
 - (c) Mentoring on how to conduct focus groups, surveys and questionnaires
 - (d) Guidance on Qualitative Data Analysis using methods such as content analysis and grounded theory
 - (e) Extensive hands on training on applying for Research Ethics Approvals
2. Inculcate a culture of Quick and Dirty Prototyping by:
 - (a) Encouraging fast hand sketching of concepts and reduce reliance on rendering and rendered images
 - (b) Exploring various materials for visualisation of prototypes (foam, cardboard, light timber and paper)
 - (c) Reducing the tendency of over-obsession with one concept through 2a) and 2b)
3. Promote High fidelity and high functionality by:
 - (a) Exposure and awareness to Arduino and its sensory possibilities amongst other hardware programming software using both Arduino (script) and Ardublock (visual) integrated development environments (IDE)
 - (b) Instilling a hacking mentality by utilising open source material (off the shelf artefacts, tools, code exemplars from online resources, etc.)
4. Iterative Concept Design and Research Process (a) where possible; iterate through both concept design and user feedback elicitation to arrive at a set of design guidelines and/or design concepts for further implementation.

In summary, our supervision, advice and training framework to our students was primarily based on a design thinking approach including hands-on and action research based approach; i.e. quick and dirty prototyping, fast hand sketching, rapid prototyping, participatory design and iterative user involvement.

2. CASE: INDUSTRIAL DESIGN HONOURS PROJECT

In this section we document our experiences of supervising and running two separate honours projects where we inculcated an HCI led and design thinking based methodology. The approach, design methodology and supervision arrangement of both projects was similar hence we present both endeavours collectively; only differentiated over our insights acquired throughout each of the steps in the design thinking process. Both projects were supported and drafted in consultation with a key industrial partner in InfaSecure; based in Penrith, Australia. The company is primarily concerned with the manufacture of child restraint seats (CRS) of all types and their associated accessories. In addition the company is involved in the design and innovation of interactive toys for children, in particular for education and entertainment. The initial drafting of the research problem for both projects was primarily sourced through secondary research and extensive discussions with the marketing, R&D and design team of the company. The first project aimed to reduce driver distraction by leveraging the design of existing child restraint systems so as to inform the driver in a salient, subtle and discreet manner the well being of their child. The second project aimed to promote learning through play by investigating the design of sports toys that could promote physical activity and social responsiveness. Although the industry partner had a key role to play in the design process (elements of which we elaborate on shortly), the research investigation was carried out by the two Industrial Design students in house under the supervision of the first two authors. Both projects followed an iterative and user centered approach as their design process with elements from design thinking sprinkled throughout. This process is summarised in a flow chart (See Figure 1). Many of the intermediate steps and techniques were driven by methods from the IDEO method cards. The design space was initially explored and funneled through semantic maps/concept maps/collages. Thereafter, based on industry feedback and secondary

research a first set of initial design guidelines were drafted. Using the keywords expressed in the maps and the set of design guidelines the students were then encouraged to quickly initiate hand-drawn concept sketches of possible product designs - typically ranging between at least 3-5 concepts per key design feature. In a typical brainstorming fashion students were advised not to critique their design ideas at this juncture.

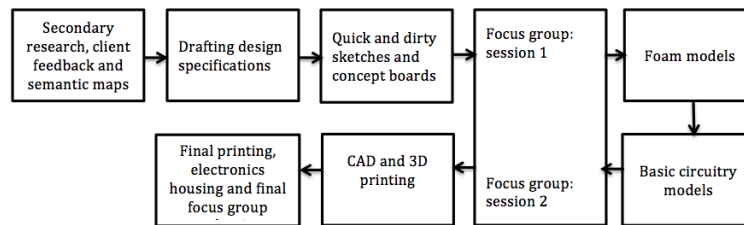


Figure 1. Flow chart of design process

2.1 Low and Hi-Fidelity Prototyping

Prior to obtaining feedback on their concepts from users, a pre-selection of a set of concepts was achieved through the Questions Options and Criteria Technique (QoC) (Maclean et al., 1991). The outlining of design rationale allowed the students to explore a wide variety of concepts and ultimately iterate through them. Thereafter concept boards with rendered sketches were created and evaluated with users (in this case parents in both projects). By this time the necessary ethics approvals had been attained to conduct primary research with human participants. We strongly recommended the students to acquire initial feedback even by using concept boards (See Figure 2). The main aim was to elicit user feedback and user insights as early in the design process as possible. Hence focus groups were conducted at the site of the industrial partner where they invited key customers (parents) from their product launch Facebook group. Since this was the first instance when the team (the students in particular) were engaging with the user; the initial phase of each focus group aimed to conduct user requirements generation; i.e. what are the current usage patterns of the concerned devices (Child restraint systems or educational toys), what are the purchasing requirements, what are the problems faced with the existing devices and are there any wish lists, etc. The second phase of the focus group concentrated on discussing the concepts via the concept boards. Qualitative Data was recorded and insights gained contributed towards the modification of design concepts but also allowed the research team to rank the concepts in terms of preference. In the subsequent design phase a more hands on approach was followed and the phase of prototyping commenced. The students incorporated bodystorming (Oulasvirta et al., 2003) with anthropometric analysis (Kroemer et al., 2001) and foam modeling to envision their intended prototypes and the environment they expected the products to be deployed in. In the child restraint project a dummy wooden interior of a car was crafted to and foam models were extensively created to allow a tangible representation of the design ideas (See Figure 3).

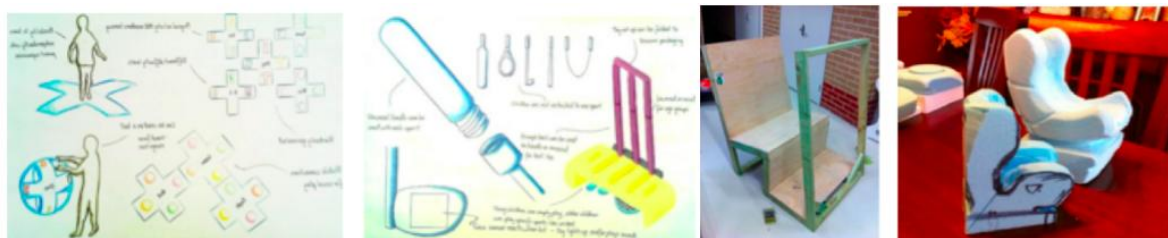


Figure 2. Concept Boards and Foam Models

In the second half of the project the students began to concentrate on developing their prototyping skills using Arduino. Both students did not have a strong programming background so the initial learning activities were built around the visual software ArduBlock with eventual transitions to using the standard Arduino IDE. In addition, the supervisory team and the students co-created and coded several off the shelf examples together to gain a sense of programming with electronics. Deliberately we did not force the students to envision the integration of the electronics into their final product but rather persuaded them to play around and experiment with their circuits. This led to the creation of many un-cased and breadboard based circuits,

which proved to be very useful for demonstration purposes (See Figure 3). Such circuits and demos were quick to assemble and dismantle which allowed the students to persist with their iterative design process and consequently showcase not one but several prototypes. The current phase was ripe for further user intervention and a second round of focus groups was conducted where the more tangible prototypes were displayed (foam models and circuit demonstrations). The focus groups were again conducted at the site of the Industrial partner with the relevant target group and were utilised to further hone in on the final design concept. The final model of the child restraint seat was a subtle awareness system that would transmit the environmental temperature of the child through a change in color of LED strips (blue indicating a cool ambience; red indicating hot, etc.). In the learning through play project a toy cricket bat was designed that would give force/audio/visual feedback on the quality of the shot by the child.

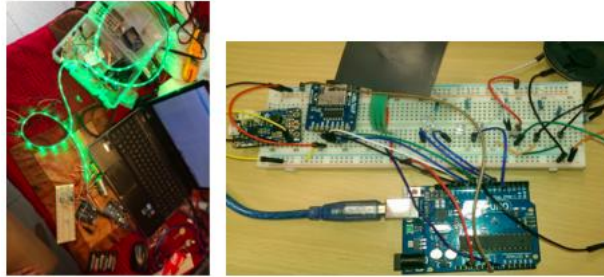


Figure 3. Arduino open circuits

Utilising insights gained from the second round of user evaluations a final design concept was converged to and the phase of final prototyping commenced. Key decisions at this iteration revolved around material analysis, structural requirements, housing of electrical components and resolution of finalised look and feel/aesthetics. Detailed component sketching led to the creation of Initial Computer Aided Design (CAD) models (of a reduced scale initially) which were then rapid prototyped (See Figure 4). The students had a wide range of 3D printers at their disposal, which allowed for customised 3D printing; such as low cost prints for initial CAD models. The basic CAD models enabled trying out casing and the layout of the electronics (See Figure 4). The final CAD models were then prototyped using high quality 3D printers (Objet) and the electronic components were subsequently integrated through soldering (See Figure 4). Final round of user evaluations with the developed models was conducted as focus groups to determine the success of the prototypes and identify future design recommendations. As with the other focus groups these concluding sessions were also conducted at the site of the industrial partner.



Figure 4. L to R: intermediate 3D printouts and electronic casings - toy bat only; Final renderings and images of completed product - both products

3. RESULTS AND REFLECTIONS

The discussed design process in Industrial Design projects is now reflected upon and reflections are presented which are of value to other Industrial Design academics and practitioners. We followed a distinctly radical design approach to conventional Industrial Design projects as conventionally executed in our faculty. There was a clear preference and emphasis on striving for functionality over aesthetics and other form based factors. Aesthetics is an important principle but one which we encouraged students to pursue towards the end

of their project. We collectively infused creative intelligence into the projects as a joint design team (industry partner, us as supervisors, non ID academics as experts and the students as designers); providing further evidence that design thinking is best applied within a multidisciplinary team (Seidel and Fixson, 2013). We generally achieved positive and encouraging outcomes through the application of design thinking in our ID program. Additional reflections and experiences with regards to the design process are outlined hereunder.

3.1 Human Ethics

Being based in Australia our faculty is bounded by the requirements of ethics approvals for any research involving human participants. The process involves red-tape and can be a burden for undergraduate students. In this particular instance we as supervisors facilitated the students so that their ethics approval was attained early on in the project. Both of our projects involved preschool children as one of the key stakeholders; however obtaining ethics approval to conduct research with children in our institute is relatively complex and would have been difficult to resolve within the timeline of the projects. Alternatively all research was conducted with parents as the other half of the target market. We are of the opinion that ethics is an issue of being professional rather than documenting several pages with methodological details. A middle ground will be ideal for undergraduate students especially design students where involving the user at every iteration is imperative. We are in discussions with our Human Ethics once with the aim to explore and finalise a possible program ethics approval spanning the entire honours course structure.

3.2 Quality of Design Process and of End Product

In general the students appreciated the design process and were positive about the focus on hands on activities that provided them with quick and tangible results. Traditionally the ID program at our institute instills a great deal of emphasis on sketching hence the students were well equipped with the required drawing abilities. However their initial tendencies were to pursue finished and rendered sketches; it was only after cajoling from the supervisory team that they felt more comfortable with free hand sketching. The IDEO Method cards allowed a wide array of methodological possibilities and relevance of a method to their project was easy to establish. Involving the user at every iteration was a slightly unknown proposition to the students (a known tendency in ID students (Eroglu et al., 2013)) and we encouraged the students in holding mock focus groups to practice and finalise their study protocol. In addition, both students were comfortable with hands on activities, prototyping and CAD modelling. The students were constantly reminded that evaluations could also be conducted with unfinished products or rough prototypes. Evaluation with quick and dirty prototypes (concept boards, foam models and open Arduino circuits) led to rich and engaging feedback from the target user group, which were rapidly absorbed by the students to their design concepts. The students were also content with delaying the CAD development towards the end until design choices were finalised. During the user feedback elicitation stages the students were not attached or obsessed with one concept; ultimately allowing them to readily and rationally process design modifications in an unbiased manner. By enhancing the decision-making opportunities for the students in the design process we noticed that they developed a sense of ownership and responsibility with regards to the project.

The outcomes of the project were also successfully evaluated from both an academic and commercial perspective, which augurs well for the continuation of our recommended design process to upcoming honours students. Both projects attained a Distinction mark overall (> 80%) which lends some credibility to the quality of work given that the project outcomes were marked by independent examiners and experts. Furthermore the project outcomes have already been published in a HCI conference with the reviewers specifically appreciating the marriage of HCI into Industrial Design. Our industry partner is also working on the further development of the concept emerging from the child restraint project. We are also in negotiations with the legal department at our institute to pursue a patent of the toy cricket bat and its associated technology. The revised content was not only appreciated by the two students that we supervised but also by the entire honours group (on average 10 students per year) as indicated by the student feedback on unit (see Figure 5). The average ratings across a 2 year period of implementing our new vision to the honours program (2013-2015) were a distinct improvement to 2012 which was prior to introducing design thinking based changes to the program.

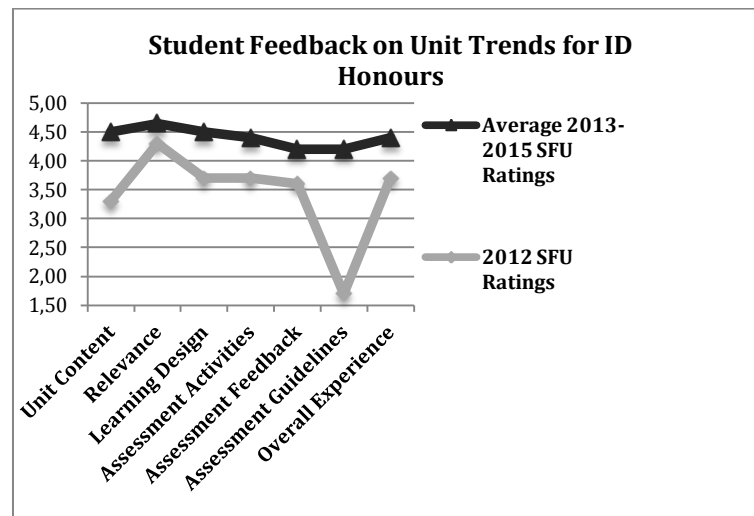


Figure 5. SFU Trends for ID Honours comparing pre & post design thinking based curriculum (max best rating is 5)

3.3 Electronics and HCI led Technology Driven Innovation

In order to develop functional products we have explored Arduino interfaces as the tool of choice. Arduino is commonly utilised as a tool for tangible and embedded prototyping in design projects offering design students a physical representation of their programming efforts (Alers and Hu, 2009). Our students had limited experience with programming hence there was a learning curve associated with their development. We gradually introduced them to the world of Arduino and hardware programming using visual tools such as ArduBlock with eventual transitions to incremental open circuits before the eventual design of the casings and housings of the electrical components. Arduino is licensed under a Creative Commons agreement hence there are sufficient open source materials which can be brought to the fore and under usage. In order to fully appreciate the potential of Arduino as an input/output interfacing platform we also introduced the students to the areas of Multimodal and Tangible interaction from HCI. We noticed the students were highly adept with any hands on activities associated with electronics programming such as the circuitry design and soldering but required assistance with coding. In the future we expect incoming honours students to be more attuned towards coding and programming because such skills are gradually finding their way in high school in Australia. The competency of technological development is already an integral component in other ID curricula around the world such as in Delft and Eindhoven (Hummels et al., 2011). In consideration of the above, we have introduced new units such as 'Programming for Designers' and 'Tangible Interaction' in our revised ID curriculum where such skills would allow students to create complex products and interactions.

3.4 Importance of the Environment

The setting of our ID faculty in a multidisciplinary school and environment largely facilitated our efforts in introducing design thinking in the honours stream. Positioned amongst the engineering and computing faculties not only did we have a wide array of 3D printers and laser cutters but also software and engineering tools (including Arduino sensors and electronics), etc. Several key design decisions pertaining to the structural integrity and electronics housing were made in close consultation with academic experts from the engineering faculty. The importance of the industry partner must also be acknowledged in the entire design process. Not only did the industry partner provide testing facilities and access to the target market but the drive to create a real life application was a source of motivation for the students.

4. CONCLUSION

There are several outcomes made in this paper that can contribute to others wanting to do a makeover of their design programs. For one, we present the key role of integrating HCI with industrial design education since

the latter is not longer measured by its functional and aesthetic attributes only. Second, we claim the need to conceive the discipline of design as a multi-disciplinary collaboration from different fields of expertise across both academic and non-academic/industrial sources. Third, it is possible to lead students by design thinking towards a more updated form of design practice in relatively short periods of time. Fourth, the co-authors recognized a way to facilitate modernization of their academic program while assisting customization of Bloom's Taxonomy for their course. Fifth, the importance of empowering students by increasing their project ownership through a iterative process from quick and dirty, low fidelity to high-fidelity prototyping and making of final presentation and reference models. Further design research and discussion is needed to elaborate on how this contribution conforms towards a new taxonomy of transformative learning based on creative intelligence beyond traditional disciplinary skills.

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